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TREATMENT CAPABILITY OF A PHYSICAL-CHEMICAL PACKAGE PLANT

J. F. Kreissl, et al

Environmental Protection Agency
Cincinnati, Ohio

April 1971

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Water Quality Office
Advanced Waste Treatment Research Laboratory
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ABSTRACT

A short-term study of a commercially-available physical-chemical waste treatment plant is reported. Results indicate that an excellent quality of effluent can be consistently obtained despite wide fluctuations of influent wastewater characteristics. Physical, chemical, and biological parameters were monitored. The short-term data obtained offer some evidence of superior treatment efficiency in terms of COD, color, turbidity, and phosphorus removals when compared to more conventional treatment methods.

TREATMENT CAPABILITY OF A PHYSICAL-CHEMICAL PACKAGE PLANT

J. F. Kreissl and J. M. Cohen*

In response to a request by the Environmental Protection Agency's Water Quality Office laboratory in Fairbanks, Alaska, the Physical and Chemical Treatment Research Program of the Robert A. Taft Water Research Center, Cincinnati, Ohio, undertook a study of a commercially-available, physical-chemical package treatment plant. This unit, Model #1100-10, manufactured by the Met-Pro Water Treatment Company of Lansdale, Pennsylvania**, was originally designed as a laundry wastewater treatment device, but the unit processes incorporated in the design were considered applicable to domestic wastewater treatment. In addition to the above request, it was noted that a significant number of applications of package waste treatment plants exist in which the inherent advantages of physical-chemical treatment are important.

Some of the major advantages of physical-chemical systems over biological treatment for small installations include:

1. Reduced land area requirements
2. Positive control of treatment
3. Insensitivity to toxic substances
4. Ability to start and stop with a minimum of effluent quality

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**Mention of manufacturer does not constitute endorsement by Environmental Protection Agency.

deterioration

5. Equal or superior removal of organics, suspended solids, turbidity, color, and phosphorus.

Physical-chemical treatment, as perceived presently, includes chemical coagulation, solids separation and adsorption. Chemical addition enables clarification by coagulation and flocculation of suspended and colloidal materials. Subsequent removal of the resultant floes by sedimentation, filtration, flotation, or any other efficient solids-separation technique can be expected to remove most of the organic matter, color and turbidity from the raw degritted sewage. Phosphorus removal would be included in this list when primary coagulants, such as aluminum or iron salts or lime are used. The adsorption step, which normally requires activated carbon, removes most of the remaining dissolved organic matter in the wastewater.

EXPERIMENTAL FACILITIES

Wastewater characteristics varied from those of a typical municipal waste to those of stormwater runoff. The variation and average values for the constituents measured during each run are displayed in Table I. Analyses of all samples were performed according to FWPCA Methods for Chemical Analysis of Water and Wastes (1).

The treatment unit was installed in the experimental wing of the Robert A. Taft Water Research Center in Cincinnati, Ohio. The flow diagram for the unit is shown schematically in Figure 1, along with the

TABLE I

RAW WASTE CHARACTERIZATION

CONSTITUENT	CONCENTRATION, mg/l	
	Average	Range
COD	330	38 - 694
COLOR (units)	48	17 - 174
TURBIDITY (units)	96	13 - > 1000
pH (units)	7.6	6.8 - 11.2
SUSPENDED SOLIDS	150	24 - 318
TOTAL HYDROLYZABLE PHOSPHORUS	10.3	1.2 - 21.6
TOTAL Fe	2.1	< 0.1 - 6.0
NH_3-N	21.1	0.8 - 225
ORGANIC-N	7.8	1.2 - 15.7

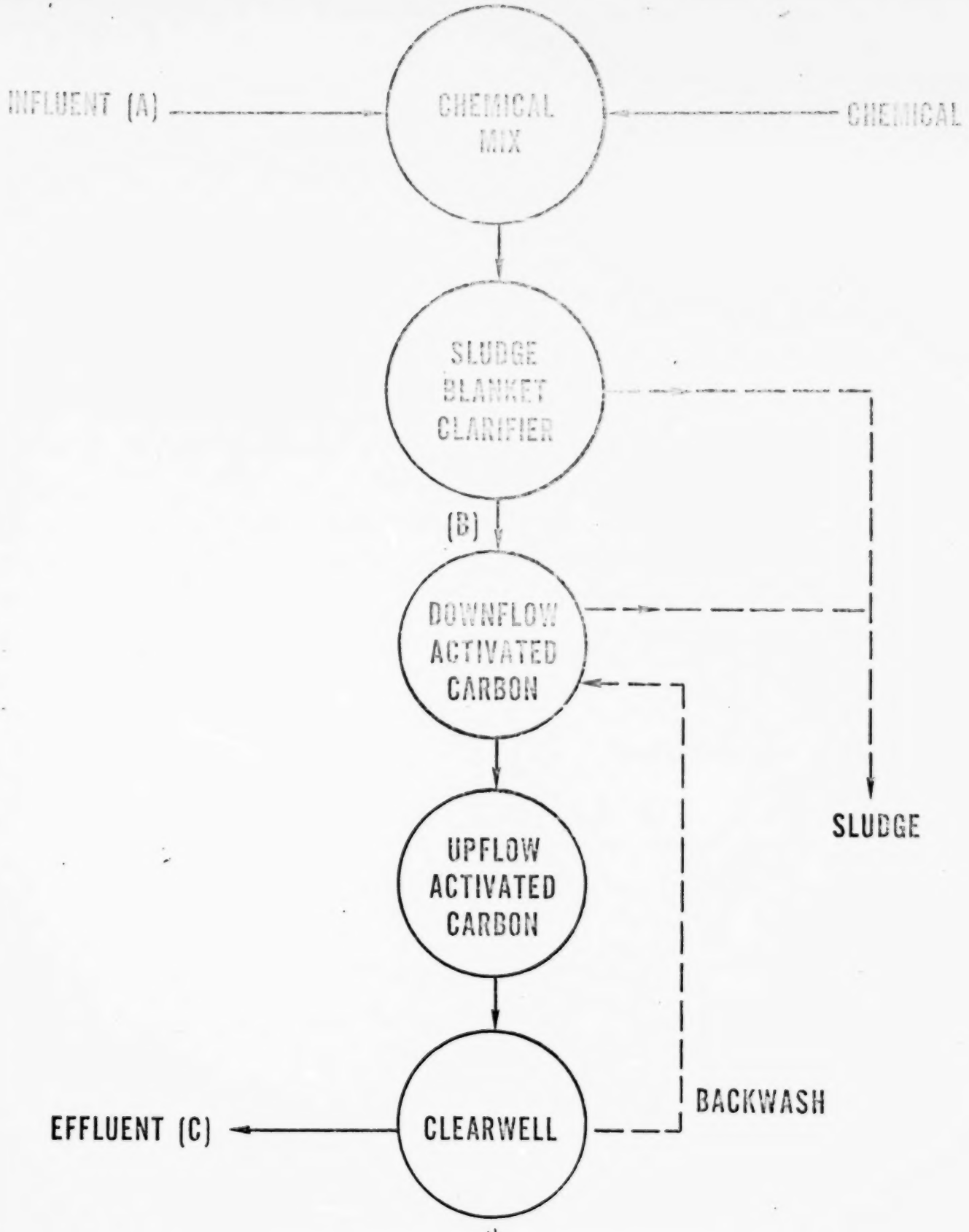

FIGURE 1. FLOW DIAGRAM

sampling points designated as A, B, and C. Comminuted and degritted wastewater (influent) was fed to a constant-head tank, shown at the right in Figure 2, from which the influent pump delivered a constant-rate flow of from 12 to 24 gpm (0.75 to 1.5 l/sec). Coagulant was mixed with the wastewater before it entered the sludge-blanket clarifier. The coagulation chemicals fed were either ferric sulfate or aluminum sulfate (alum) in dry form.

In the sludge blanket clarifier the flow traveled upward through a blanket of floc particles to the effluent weir at the surface of the unit, illustrated in Figure 3. The effluent weir of the clarifier conveyed the clarified wastewater to the filter section indicated at the left of the figure. The filter media consisted of 12x40 mesh activated carbon* underlain by anthracite coal as support media. The filtration rate through the 33 in. (84 cm) deep carbon bed varied from 1.3 to 2.5 gpm/sf (52 to 102 l/min/sq m). The filter effluent was fed to the bottom of the second-stage or upflow carbon contactor.

The two-stage carbon adsorber consisted of the downflow or filter section followed by the upflow section. Each section contained approximately 700 lb (318 kg) of activated carbon with equal empty-bed contact times of from 8 to 16 minutes for the range of flows used in this study. The mode of contacting was countercurrent as the upflow carbon was designed to replace the filter carbon upon exhaustion of the latter, while fresh carbon was to be added to the upflow section. Exhausted

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*Filtrasorb 400, manufactured by Calgon Corporation, Pittsburgh, Pa.

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FIG. 2 FRONT ELEVATION OF P-C PLANT

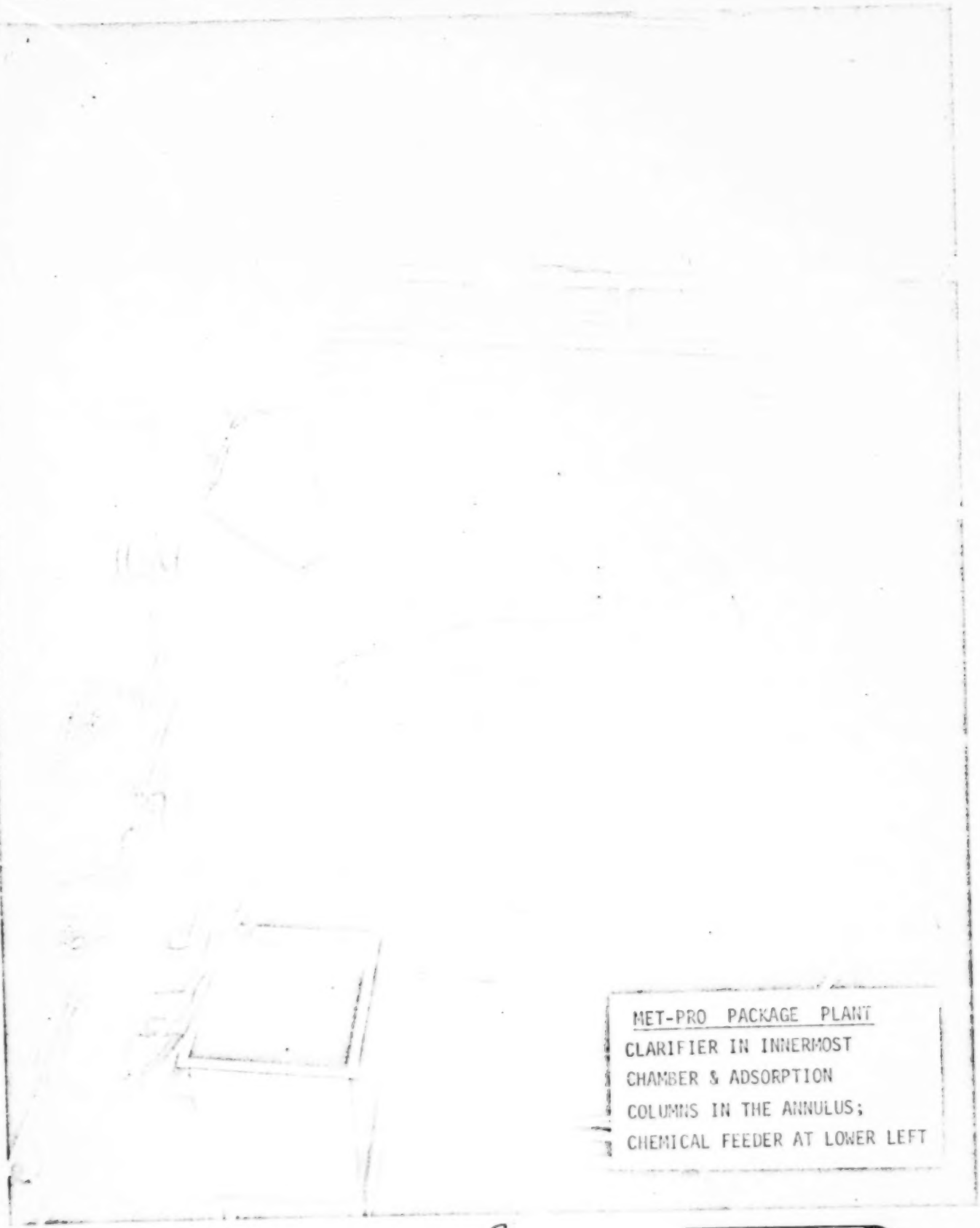

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FIG. 3 OVERHEAD VIEW OF P-C PLANT

carbon could be either incinerated or disposed of in some other manner.

From the upflow adsorber the effluent flows to a large, 750 gal (2.84 cu m), clearwell which also provides the source of backwash water. Backwash water was used at a rate of 10.5 gpm/sf (428 l/min/sq m) which, according to the carbon manufacturer (2), should have provided approximately 30 percent expansion of the filter media. A small amount of air was entrained in the backwash stream, but its effect was quite minimal.

The effluent was run to drain except for sampling and monitoring needs. Also, sludge wastage from the clarifier was run to drain during the testing period.

SAMPLING, ANALYSIS AND CONTROL TECHNIQUES

Flow rates were measured by rather crude methods due to the difficulty of access and the omission in design of any instantaneous flow measuring devices. The influent pump flow rate was measured by the "bucket and stop-watch" method, while the filter pump flow rate was determined by timing the totalizing meter rate of advancement. Dry chemical feeds were determined by weighing the amount of chemical delivered by the screw-feeder in a given period of time.

A run consisted of starting the unit in the morning and allowing it to run until it reached equilibrium. Grab samples were taken from the influent, clarifier effluent, and final effluent streams once each run after an apparent equilibrium had been achieved. Equilibrium conditions were assumed after the effluent turbidity, measured by a continuous-reading turbidimeter*, had reached a plateau of minimum turbidity for a period of time.

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*Model 1468, manufactured by Hach Chemical Company, Ames, Iowa.

Samples were analyzed for pH, turbidity, COD, total hydrolyzable phosphorus, suspended solids, color, ammonia nitrogen, organic nitrogen, and total iron in all cases. Some analyses were also made for total aluminum, TOC, and nitrite and nitrate nitrogen. The unit was run, with one exception, during the 8-hour work day; average run length was about seven hours.

RESULTS

The entire evaluation study amounted to a cumulative total of less than 200,000 gal (757 cu m) of wastewater treated. This volume is less than ten days' operation at the rated capacity of 24,000 gpd (91 cu m/day); thus, no long-term problem areas became evident. Therefore, no data are presented on the ultimate loading capacity of the carbon or on long-term maintenance and operation.

Chemical and Physical Parameters

Data on the chemical oxygen demand (COD) of the influent, clarifier effluent, and final effluent for all runs are presented in Figure 4. There are no particular trends apparent from these data other than the random fluctuations normally present in municipal wastewaters and the generally p or solids capture in the clarifier. These results indicate a consistent high quality of effluent, despite the extreme scatter exhibited by the influent and the clarifier effluent data. The frequency distribution of effluent COD concentrations is illustrated in Figure 5. This figure shows that the mean value of effluent COD from all runs was 13.0 mg/l. The consistency of these and other effluent parameters is shown in Table II.

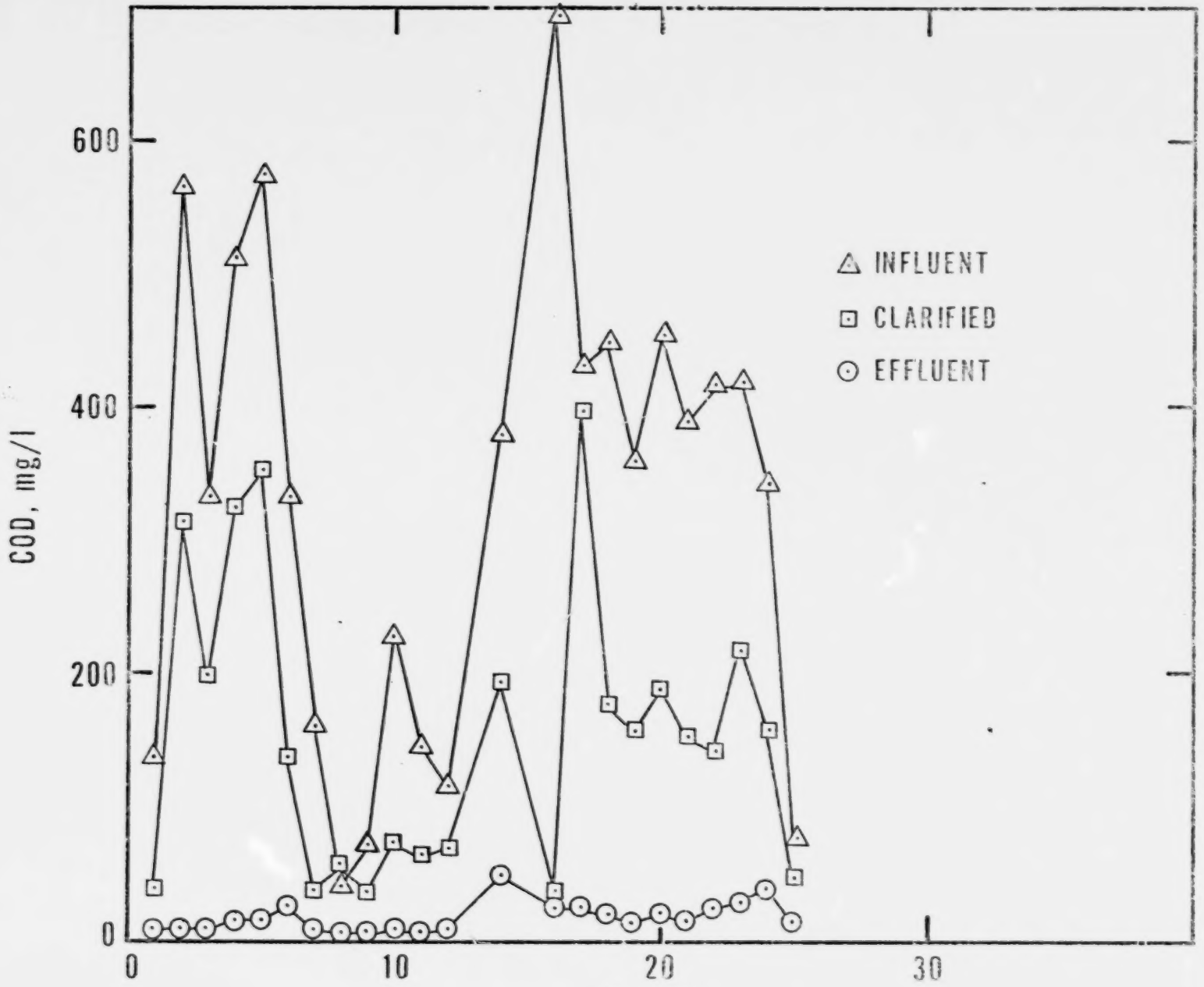

FIG. 4 COD REMOVAL

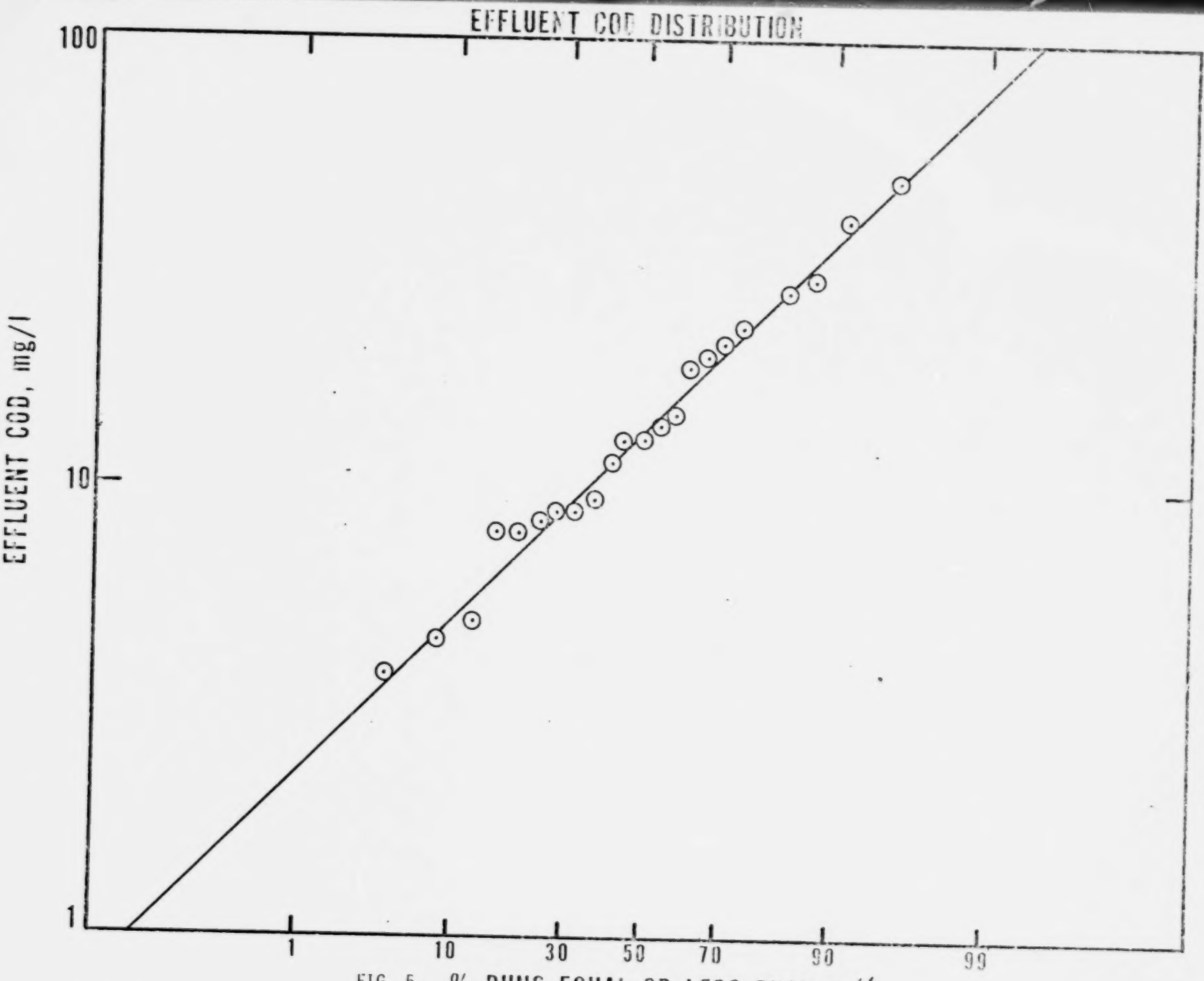
EFFLUENT COD DISTRIBUTION
EFFLUENT COD, mg/l
100
10
1
1
10
30
50
70
90
99
% RUNS EQUAL OR LESS THAN

FIG. 5

TABLE 11

EFFLUENT CHARACTERIZATION

PARAMETER (UNITS)	PERCENT OF TIME EFFLUENT LESS THAN		
	50%	70%	90%
COD (mg/l)	13	20	35
COLOR (units)	5	7	15
TURBIDITY (JU)	0.8	1.5	9.0
T.H.P (mg/l as P)	0.1	0.3	1.4
ORG.-N (mg/l)	1.5	2.0	3.0
NH_3-N (mg/l)	15	18	21
IRON (mg/l)	0.5	3.6	6.7

Effluent turbidity, as measured by the continuous-flow turbidimeter, was below one Jackson Unit (J.U.) during more than 50 percent of the runs. Grab samples, taken at the same time as those for other pollutant measurements, were tested for turbidity on a laboratory instrument*. Turbidity of the three measured streams for each run is shown in Figure 6. The color of the effluent was markedly reduced with a resultant mean of 5.4 units. Better than 80 percent of the effluent samples had color values of less than 10 units. Total hydrolyzable phosphorus in the final effluent was equal to or less than 0.1 mg/l as P during 50 percent of the runs. No odor was detected in the effluent from the unit despite the existence of a decided hydrogen sulfide odor in samples taken between the two adsorbers.

Iron concentrations in the effluent, as shown in Figure 7, ranged from less than 0.1 to 10.6 mg/l. Higher concentrations appeared toward the end of the ferric sulfate coagulation runs and continued well into the aluminum sulfate runs before subsiding in the final runs. Aluminum never exceeded one mg/l when alum was used as a coagulant. The average ammonia-nitrogen values over the entire testing period showed that there was only a 10 percent change in ammonia-nitrogen concentration through the entire unit. Organic-nitrogen concentrations followed the same general removal pattern during both phases of testing. Influent concentrations were somewhat reduced through the clarifier, followed by a substantial reduction in the carbon contactors. These data are given in Table III.

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*Model 2100, manufactured by Hach Chemical Company, Ames, Iowa.

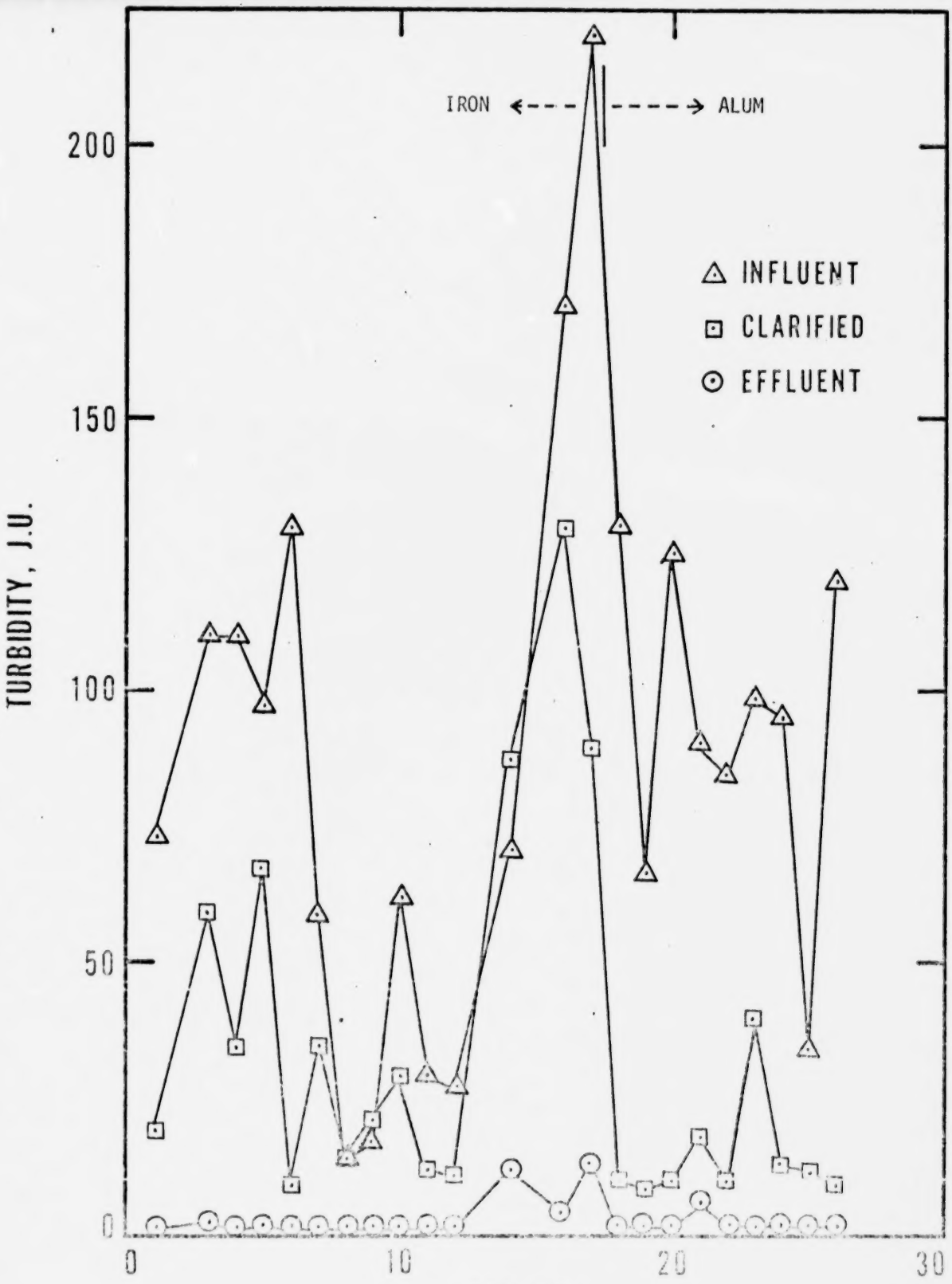

FIG. 6 TURBIDITY REMOVAL

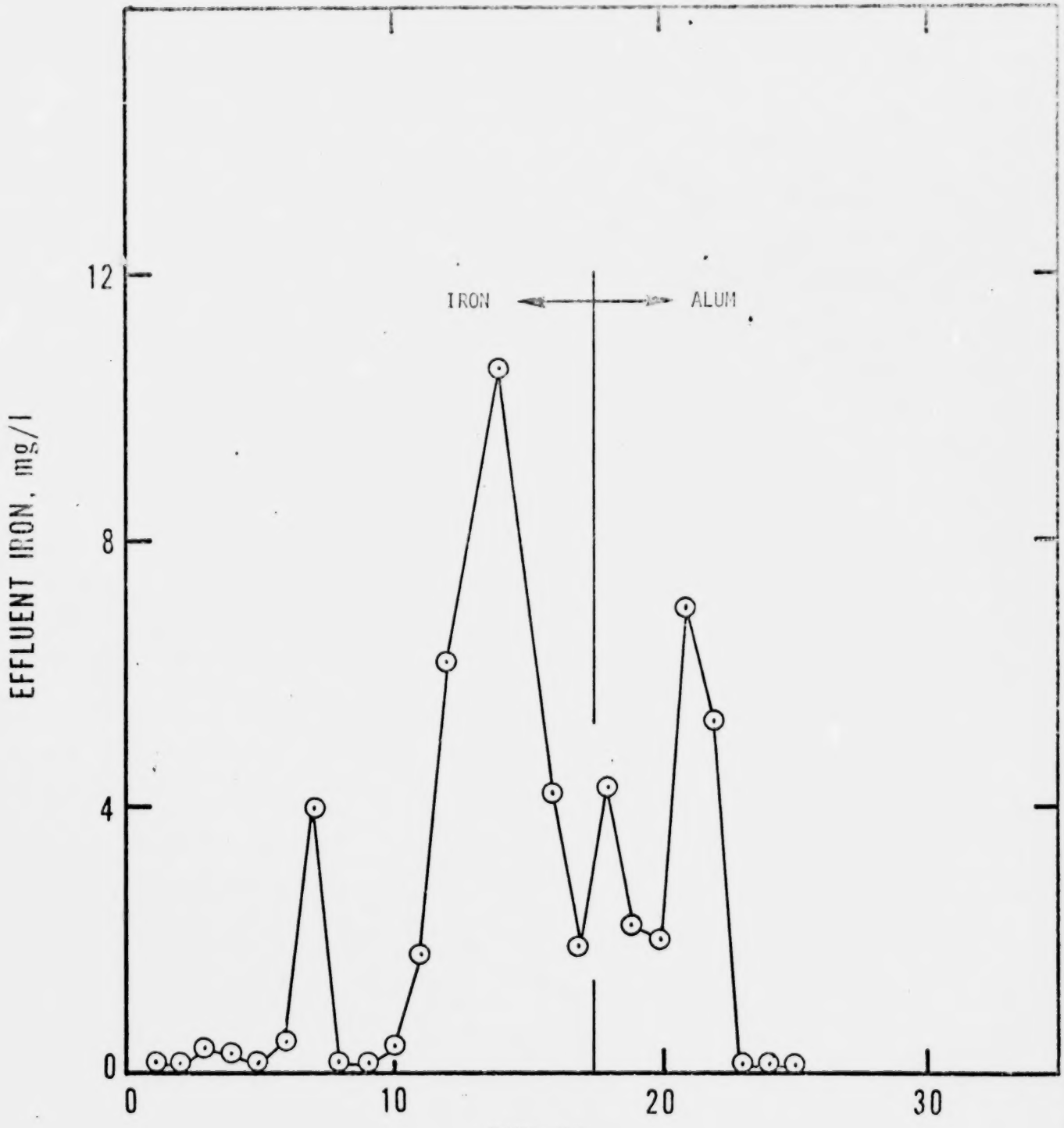

FIG. 7 RESIDUAL IRON MEASUREMENTS

TABLE III

NITROGEN DATA

SAMPLE LOCATION AND COAGULANT		NUMBER OF ANALYSES	ORGANIC NITROGEN	AMMONIA NITROGEN
Influent	Iron	15	7.2	13.0
Clarified	Iron	15	6.4	11.0
Effluent	Iron	15	1.8	10.2
Influent	Alum	8	9.1	10.0
Clarified	Alum	8	7.0	12.1
Effluent	Alum	8	1.3	18.1
Influent	Ave.	23	7.8	11.9
Clarified	Ave.	23	6.6	11.4
Effluent	Ave.	23	1.6	13.1

Biological Parameters

Bacteriological data were obtained on total count, coliforms, fecal coliforms, and fecal streptococci in the influent, clarifier effluent, and final effluent streams. The sludge-blanket clarifier removed more than 95 percent of all of these organisms based on average counts per 100 ml. Final effluent counts represent greater than 99 percent removal of coliforms, fecal coliforms, and fecal streptococci. Total count, however, showed a slight increase through the filtration and adsorption steps. These averaged data are shown in Table IV.

In order to assess the amenability of the final effluent to disinfection, it was seeded with approximately 10^4 plaque forming units (PFU) of polio virus (Mahoney) per milliliter (ml). Inactivation of these organisms by different levels of iodine and chloramine was studied in bench-scale tests. Two runs were made with three different iodine concentrations and two chloramine concentrations at 15°C. Results of these runs are illustrated in Table V. Higher concentrations of iodine imparted a faint straw color to the effluent. No free chlorine was detected in the chloramine systems. All tests were conducted at neutral pH.

Ultraviolet (UV) light was studied for disinfection of the effluent. To accomplish this, final effluent was pumped through a commercial UV device* at rates up to 5.3 gpm (20.1 l/min), which corresponds to an exposure time of 8.5 seconds. At this flow rate coliforms, fecal coliforms,

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*Model 500 SF, manufactured by Ultradynamics Corporation, Paterson, N.J.

TABLE IV

BACTERIOLOGICAL DATA

ORGANISM	INFLUENT NO./100 ml	CLARIFIED NO./100 ml	EFFLUENT NO./100 ml	OVERALL REM. %
TOTAL COUNT	6.44×10^8	1.09×10^7	1.71×10^7	97.4
TOTAL COLIFORM	2.77×10^7	2.69×10^5	1.42×10^5	99.5
FECAL COLIFORM	5.90×10^6	2.45×10^5	1.71×10^4	99.7
FECAL STREPTOCOCCI	1.45×10^6	1.91×10^4	1.44×10^3	99.9

TABLE V

POLIOVIRUS 1 INACTIVATION AT 15°C

RUN NO.	DISINFECTANT Chloramine or Iodine	CONCENTRATION Dose mg/l	Final Residual	pH units	KILL TIME 99% minutes	99.9% minutes
I	Iodine	5	3.00	7.3	16	25
	Iodine	1	0.21	7.5	84	150
	Chloramine	15	14.9	7.3	25	60
II	Iodine	5	3.72	7.5	11	20
	Iodine	2	1.58	7.4	27	44
	Chloramine	22	17.7	7.6	6	24

and fecal streptococci were reduced to 87, > 2, and > 2 organisms per 100 ml, respectively.

Sludge Samples

Spot samples from the sludge blanket were analyzed for filter yield, cake moisture content, specific resistance, compressibility, and settleability. Average results for ferric sulfate and aluminum sulfate blanket sludges are given in Table VI. Sludge analyses were made in the manner outlined by Mulbarger, et al., (3). Results indicate that the ferric sludge could be more readily thickened and dewatered than the alum sludge. From the table it can be seen that the more concentrated iron sludge settled more readily than the thinner alum sludge and yielded a much drier cake upon filtration.

Operational Study

In order to determine the ability of the unit to react to an "on-off" mode of operation, two runs were performed. The unit was drained and then filled with tapwater prior to startup. The results of these runs are illustrated in Figures 8 and 9. Figure 8 indicates that effluent turbidities never seriously degraded and leveled off in approximately four hours. Total organic carbon analyses of the effluent show similar results in Figure 9. Although there is a period of less efficient performance shortly after startup, the effluent quality is still acceptable. These figures provide evidence that the physical-chemical package plant can respond adequately to an on-off mode of

TABLE VI

SLUDGE CHARACTERISTICS

PARAMETER Units	IRON Blanket	ALUM Blanket
SUSPENDED SOLIDS (mg/l)	2,850	1,912
FILTER YIELD (lb.solids/ft^2/hr)	0.152	0.062
SPECIFIC RESISTANCE (sec^2/g)	1.56×10^6	2.08×10^6
CAKE MOISTURE (lb. H_2O/lb. solids)	2.57	4.60
COMPRESSIBILITY	0.55	0.77
SETTLEABILITY (ml/min)	67.5	57.0

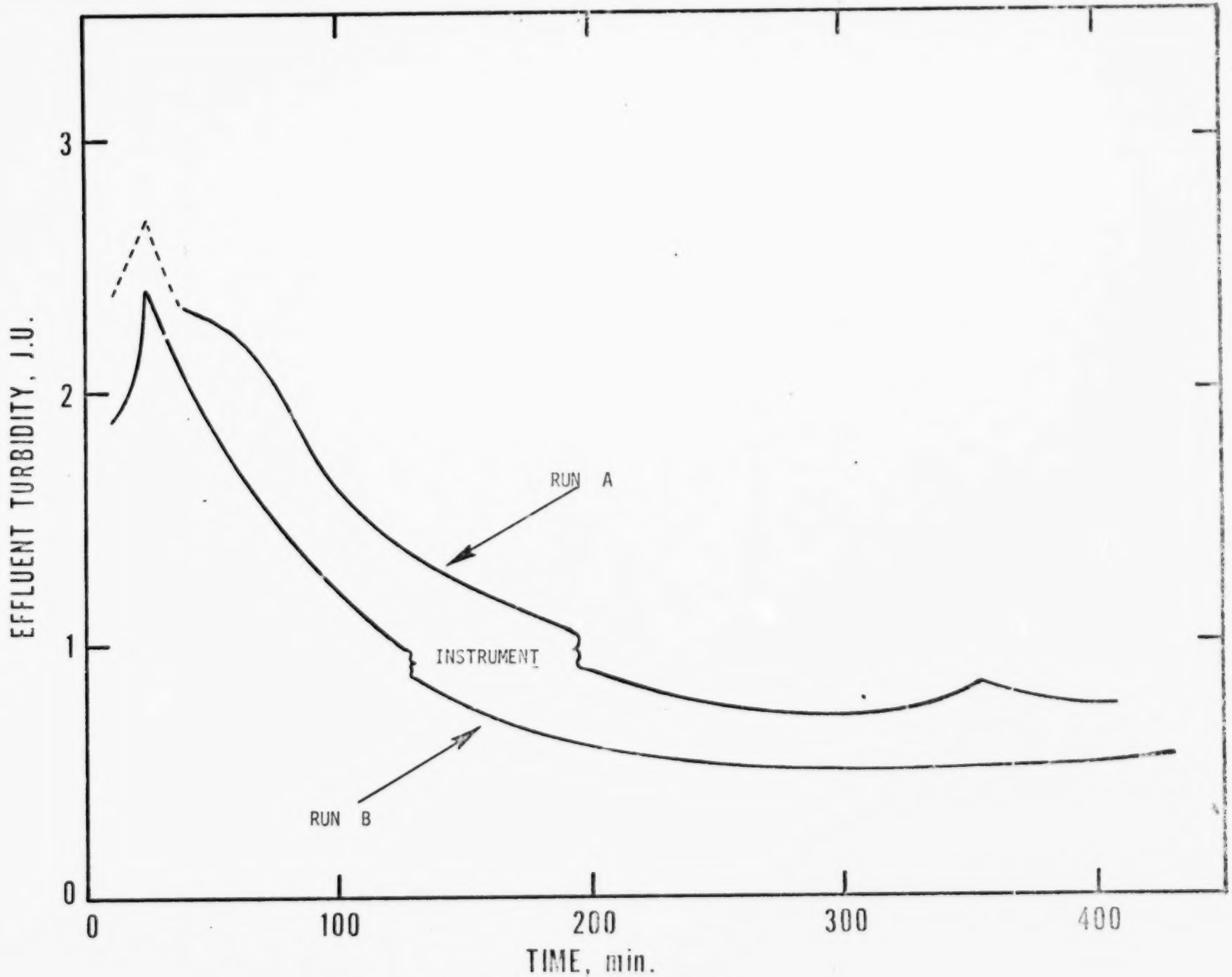


FIG . 8 TURBIDITY EQUILIBRIUM

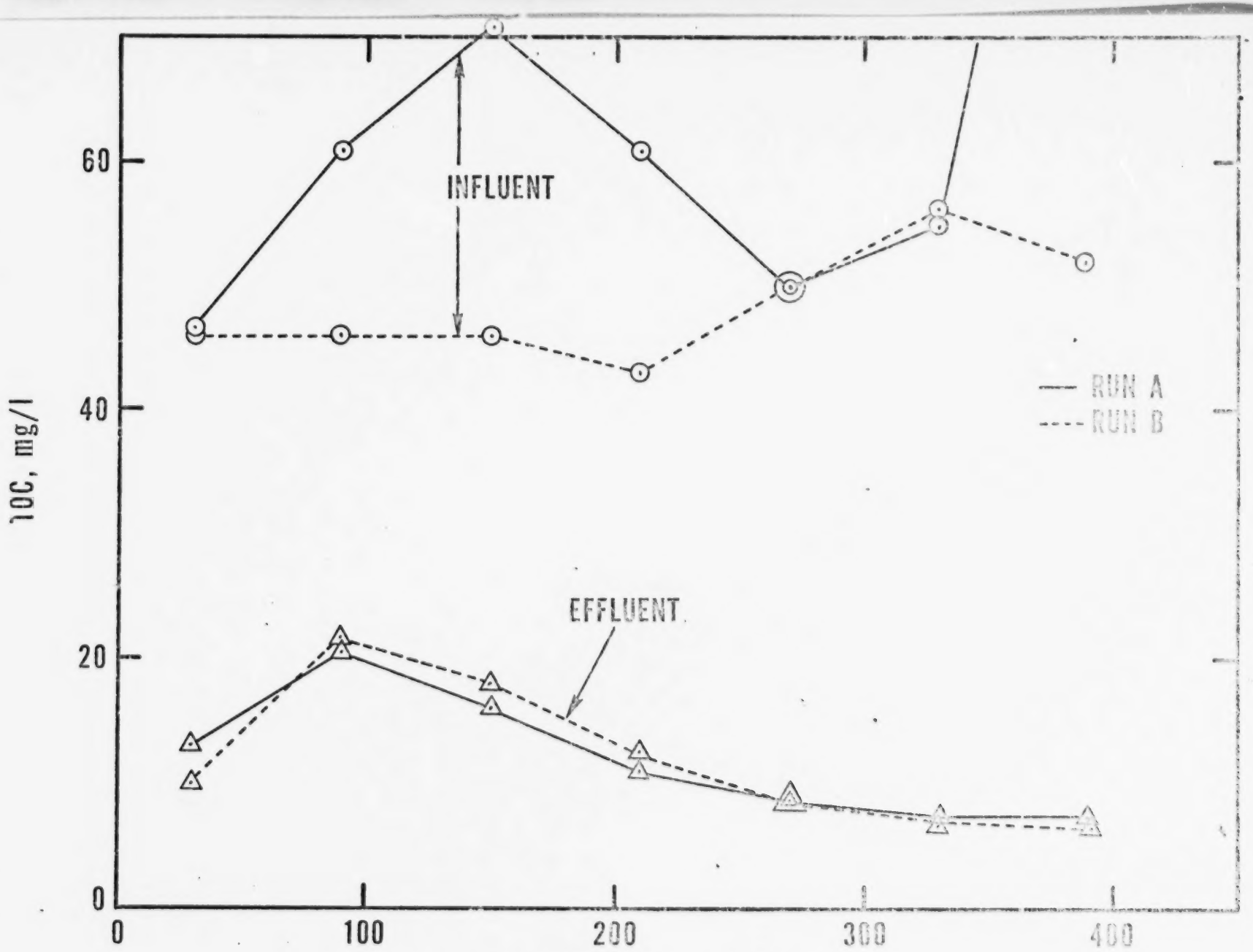


FIGURE 9

TOTAL ORGANIC CARBON EQUILIBRIUM

operation. This is especially significant since no blanket existed at the start of these runs. During regular operation a settled blanket should further minimize effluent degradations occurring after startup.

Physical Parameters

Since the most readily-judged measures of effluent quality are the physical or aesthetic properties, turbidity, color, and odor, it is noteworthy that the effluent from the unit represented high removals of these parameters. Laboratory measurements of effluent turbidities yielded a median value of 0.77 J.U. for the runs. The overall excellence of these readings can be seen when compared to the U.S. Public Health Service (USPHS) drinking water maximum value of 5 J.U. (4) which was exceeded in only 15 percent of the runs. These results are consistent with Weber, et al. (5), who obtained an average effluent turbidity of one J.U. with a similar physical-chemical system treating primary effluent.

Coupled with this excellent clarity was a consistently low level of color. The median value of color was 5.4 units. When compared to USPHS drinking water maximum of 15 units, this level was exceeded in only 10 percent of the runs. These results are consistent with previous color removal data reported for physical-chemical processes applied as tertiary treatment (6,7).

The threshold odor test was not performed during the experimental period. However, no odor was detected in the final effluent during any of the test runs. A decided hydrogen sulfide (H_2S) odor did emanate from samples taken between the downflow and upflow adsorbers, but it

was not evident in the effluent stream from the upflow carbon section. Weber, et al., noted H_2S odors in their effluent occasionally during the warmer months of the year.

It should be noted from this discussion that from the standpoint of physical or aesthetic properties the final effluent from this treatment unit appeared to be generally comparable to drinking water. Although the chemical and biological properties of this effluent belie any such comparability, such comparisons greatly enhance its acceptability to the general public.

Chemical Parameters

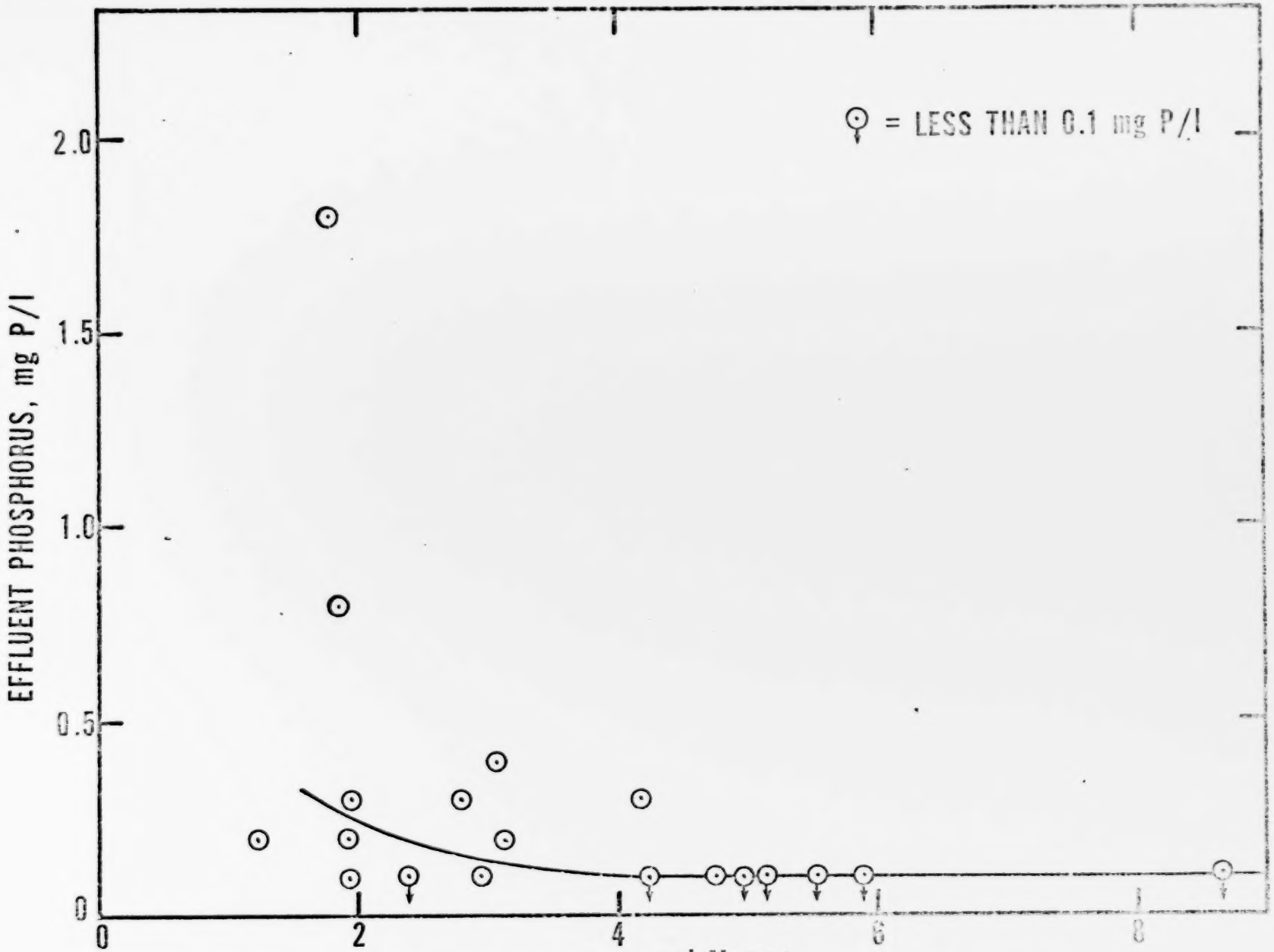
Effluent COD was quite low despite the wide fluctuations of the influent and the clarifier effluent. This consistently low effluent COD suggested that COD removal efficiencies by filtration and adsorption were related to the concentration of COD in the clarifier effluent. Since dissolved and total COD values were not differentiated in the course of this evaluation, the reason for this compensatory removal pattern can only be hypothesized. Since activated carbon adsorption of dissolved organics is more efficient when higher COD concentrations are applied to a given adsorber, this concentration-gradient or driving force could be significant. It is more likely, however, that the increased COD removal efficiencies were due to increased organic solids carryover and removal in the filtration step. Previous studies of clarification have shown an interdependence of coagulation and filtration processes (8). The median influent and effluent COD concentrations of 380 and 13 mg/l, respectively,

represent a removal efficiency of 96.6 percent, but this form of data analysis, i.e. removal efficiencies, must be considered within the limitations of the grab sampling technique.

Total hydrolyzable phosphorus concentrations were quite low in the final effluent. The concentrations were 0.1 mg/l as P or lower during 50 percent of the runs and did not exceed 0.4 mg/l as P during 80 percent of the runs. Figure 10 illustrates the dependence of effluent phosphorus concentrations on the mole ratio of coagulant metal to influent phosphorus concentrations. These ratios are merely the results of attempts to properly clarify the wastewater and not the product of planned phosphorus removal efforts.

Iron concentrations in the effluent from the unit were erratic as shown previously in Figure 7. It appears that operator error, resulting in heavy overdosing of iron coagulant, was the major cause of the breakthrough. Subsequent leakage during the remainder of the iron and early aluminum runs was probably due to the solubilization of the iron compounds accumulated in the adsorbers during the overdosing period. Strong hydrogen sulfide odors between the adsorbers were indicative of reducing conditions at this point in the process. No relationship between residual iron and phosphorus concentrations was in evidence during these breakthrough periods. Effluent aluminum concentrations were always less than 0.1 mg/l during the runs where this cation was used for coagulation.

The median organic nitrogen concentration in the effluent from the unit was 1.5 mg/l as nitrogen. This value is in agreement with Weber, et al.,



RESIDUAL PHOSPHORUS vs. COAGULANT DOSE

FIGURE 10

and Van Vuuren, et al., (9) who indicate a final effluent concentration of approximately 1 mg/l as N for primary effluent treatment and Bishop, et al., (10) who reported generally complete organic nitrogen removal through the physical-chemical treatment of raw sewage. The ammonia-nitrogen concentration was generally unchanged through the unit. Weber, et al., Bishop, et al., and Van Vuuren, et al., also noted no significant change in this parameter. As with most physical-chemical treatment schemes and many biological systems, the ammonia-nitrogen in the effluent may present some difficulty in post-chlorination treatment and in receiving waters.

Biological Parameters

Bacteria removal by biological waste treatment has been reported by Kabler (11) and Clarke, et al. (12). The former indicated total count and coliform reductions of 90 to 98 and 91 to 99 percent respectively, by an activated sludge system. The latter show mean coliform and fecal streptococci reductions of 97.0 and 95.6 percent, respectively, by a bench-scale activated sludge unit. Culp and Culp (6) also report total coliform removals of 99.0 percent through the activated sludge plant at the South Tahoe Public Utility District. Average reductions of 97.4, 99.5, and 99.3 percent for total count, coliforms, and fecal streptococci, respectively, by the physical-chemical system studied represent equal or better removal of these organisms by this method of treatment. The previously-noted phenomena of increased total count through the activated carbon adsorbers is consistent with the observations of others (5,10). The quantitative role of these bacteria in the adsorption columns

has not been determined as yet. No viral data were obtained during this study.

Effluent disinfection by ultraviolet (UV) radiation, iodine, and chloramines was investigated. Disinfection of the unit effluent with the UV device reduced total coliforms, fecal coliforms, and fecal streptococci in that stream by 99.7, > 99.8 and >98.3 percent, respectively. This method of disinfection was applicable due to the excellent quality of the effluent. High concentrations of turbidity, color, and iron would interfere with UV penetration (13). It was noted visually in a crude way that biological regrowth was prevented in an irradiated sample for six months, while a sample of the same effluent which was not subjected to UV radiation demonstrated noticeable regrowth within one week.

Virus disinfection data have significance in that they indicate the time-concentration relationships required for inactivation of poliovirus I, directly, and other virus forms and bacteria, indirectly. At the neutral pH values used in this study, 2 mg/l of iodine appears to be near equivalent to 15 mg/l of chloramine in terms of 99 percent inactivation, while 5 mg/l of iodine and 22 mg/l of chloramine yield similar results for 99.9 percent inactivation. This type of study provides a basis for choosing a disinfection system that can be employed with the physical-chemical unit.

Coagulants

As previously noted, both Fe(III), in the form of $Fe_2(SO_4)_3 \cdot 7\ H_2O$, and Al(III) in the form of $Al_2(SO_4)_3 \cdot 14.5\ H_2O$, were used as the

coagulants in this study. The ferric sulfate created some problems because of the design of the package plant. The relatively insoluble "lumps" in the granular compound plugged the more constricted sections of the discharge line of the influent pump. For the purpose of the study this was circumvented by sieving the ferric sulfate to remove these larger agglomerates. In the field this would necessitate some sort of grinding or crushing step prior to use for a system of this particular design. Also, pH values of less than 3.0 were found in the chemical mixing chamber, a highly corrosive condition which culminated in the development of leaks in that chamber. The iron coagulant did result in an erratic residual in the final effluent. Although this has been attributed to some operational difficulties in the main, this phenomenon has been noted elsewhere where this coagulant has been used (14). Alum appeared to yield a better floc blanket as well as offering less difficulty in terms of operation and maintenance. The treatment results in terms of parameters other than iron, however, show very little to chose between the two coagulants.

Costs

No power consumption data were obtained during this study, but it can be roughly calculated that the maximum current is 10 amperes drawn from a 200 volt source. This would amount to approximately 2.2 kilowatt-hours per 1000 gal (3.8 cu m), or about 2.2 cents per 1000 gal (3.8 cu m) on the basis of 1¢/Kwh. Chemical costs are shown in Table VII. These are FOB costs and do not include freight (15). Coagulant requirements

TABLE VII

CHEMICAL COSTS

CHEMICAL	QUANTITY 1000 gal	COST quantity	COST 1000 gal
ALUMINUM SULFATE	2.51 lb	2.91¢/lb	7.3¢
FERRIC SULFATE	2.51	2.16	5.4
ACTIVATED CARBON			
*Cap. = 0.50	1.67	32	53.5
Cap. = 0.75	1.25	32	40.0
Cap. = 1.00	0.84	32	26.8

LOW: Ferric Sulfate + Carbon (Cap. = 1.00) = 32.2¢

HIGH: Aluminum Sulfate + Carbon (Cap. = 0.50) = 60.8¢

*Cap. represents the organic removal capability: lb. COD/lb carbon

are based on the average dosages used in this study. The ultimate capacity of the carbon to remove organics as measured by COD was not determined due to the limited duration of the study. Three ranges are given for costing purposes in the table. These ranges are representative of reported data of other investigators (16,17). COD removals for this study were excellent at termination which represented a total organic loading of only 0.013 lb COD/lb carbon, including removal by filtration. The overall removal through the filtration-adsorption part of the unit averaged approximately 150 mg/l of COD during the testing period. Since filtration and adsorption removals of COD were not differentiated during the study, an average COD removal by the carbon of 100 mg/l was estimated for determining costs in this table.

Comparison of the costs of effluent disinfection using chloramine and iodine can be estimated by the chemical costs for 22 mg/l of chloramine and 5 mg/l of iodine both of which required approximately the same contact time for 99.9 percent kill of poliovirus 1. Chlorine added as calcium hypochlorite for the chloramine system would cost about 6.6¢/1000 gal (3.8 cu m), while chlorine and potassium iodide for the iodine system would cost approximately 10.4¢/1000 gal (3.8 cu m). If 2 mg/l of iodine were compared with 15 mg/l of chloramine, both requiring similar times for 99 percent inactivation, the chemical costs are 6.4 and 4.6¢/1000 gal (3.8 cu m), respectively. The final choice for disinfection will have to take into account costs, such as these, as well as health and aesthetic aspects in determining whether iodine, chlorine, ultraviolet, or some other means of disinfection is most desirable in any given application.

Possible Applications

The quality of the effluent and operation characteristics that a number of possible applications for systems utilizing this form of treatment suggest themselves. The ability of such a system to operate with an on-off mode while still producing a high-quality effluent would make its use for parks, rest stations, and recreational facilities such as marinas, ski resorts, and other seasonal installations quite promising. Small waste flows containing toxic compounds or requiring phosphorus removal to meet standards are prime candidates for systems of this type, whether they be industrial, agricultural, or municipal in nature. In areas where fresh water sources are either scarce or prohibitively expensive, the effluent produced by physical-chemical package units could be reused with proper disinfection for toilet-flushing or other non-potable purposes. The toilet-flushing standard for physical or esthetic parameters suggested by Bailey, et al. (18), were never exceeded during the study. These limits were 20, 30, and 6 units for turbidity, color, and odor, respectively.

SUMMARY AND CONCLUSIONS

A short-term study of the treatment capabilities of a physical-chemical package plant indicates that a high quality effluent can be obtained by that treatment system. The principal conclusions are:

1. Effluent COD was consistently low despite a wide range of flows and variations in influent COD, and coagulation efficiency.
2. Color, odor, and turbidity values indicated a high quality effluent.

3. Removal of coliforms was equal to or better than that obtained in activated-sludge treatment.
4. The stop-and-start mode of operation did not produce any significant degradation of effluent quality as measured by turbidity and TOC.
5. Disinfection of the final effluent is possible with chlorine, iodine, or ultraviolet light.
6. No conclusions can be drawn from this study concerning long-term maintenance and operational difficulties.

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